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OFFICE OF NAVAL RESEARCH

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Technical Report No. 1

The Replacement of Precious Metal Thick Film Inks Using Conductive Polymer Technology

Phase I: Feasibility Study

First Interim Report

by

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THE REPLACEMENT OF PRECIOUS METAL THICK FILM INKS USING CONDUCTIVE POLYMER TECHNOLOGY

Phase I: Feasibility Study

First Interim Report

Abstract

This is the First Interim Report on the Feasibility of Replacement of Precious Metals in Thick Film Technology with Conductive Polymer Materials.

The initial phase of this study has concentrated on a literature review of existing conductive polymer technology, and preliminary experimentation utilizing conductive polymer materials in thick film circuit applications.

Introduction

A detailed discussion of conductive polymer methodology shall be given in the Final Feasibility Report. Likewise, a more expansive description of polymer thick film (PTF) technology and its use in electrical circuitry will be presented. Simply stated, PTF's are various "thick films" (typically approximately 0.001") which form the conductive, resistive, dielectric and sealant layers in a circuit. These are analogous to discrete components such as capacitrs or resistors in a conventional monolithic printed circuit board (PCB). Most PTF systems have a precious metal as the conductive phase. These materials are costly and many considered strategic materials--those that are considered vital to U.S. military/industrial consumers, but are not domestically available.

Conductive polymers are essentially synthetic metals. They possess the electrical transfer properties of the classic metals (e.g. copper, silver, platinum) but are actually specially prepared organic or inorganic polymers. The feasibility of combining the nascent technology of synthetic metals and the growing area of PTF circuitry, exists theoretically, but requires practical application.

Conductive Polymers - Literature Review

The majority of the time in the initial phase of the Feasibility Study was used to conduct a literature review of conductive polymer technology. Examples of existing conductive polymer materials are listed:

Organic	Inorganic
Polyacetylene	Polythiazyl
Polypyrole	Graphite
Poly (p-phenylene vinylene)	Polyphosphazene
Polyphenelyne Sulphide	Pthalocyamines
	Poly Sulfur Nitride

All conductive polymers become that way through doping or intercalation of various inorganic charged species (e.g. AsF_6^-, Br^-, ClO_4^-). Of all the polymers which have been studied, the polyacetylenes have been researched the most (1 - 5). Despite greatly improved methods of synthesis (6), and stability (7), only limited success has been achieved as to practical applications (8, 9). None of these applications is yet commercially viable. The number of potential conductive polymers and copolymers is virtually unlimited. Current emphasis is on development of more stable and tractable (10) materials. Environmental instability and intractability are the two primary obstacles to expansion of this technology into useful application.

PTF Materials Requirements

Briefly, a review of the requirements of any PTF material is necessary. These requirements include:

1. Conductivity
2. Environmental Stability
3. Electrical Stability
4. Flexibility
5. Adhesion
6. Compatibility
7. Convenient Applicability
8. Cost

Any material which is to be used in a PTF regime will have to match or surpass the performance of existing materials based on these criteria. The goal of this study is to evaluate whether conductive polymers/synthetic metals might possibly meet these criteria. The goal of Phase II (if granted) will be to develop methodologies which can be used to bring a PTF/Conductive Polymer combination into existence.

Preliminary Experimentation

The limited time offered in this Phase I study, required outside consultation for the synthesis and characterization of selected conductive polymers. The expertise in the conductive polymer field is concentrated at several University Research Centers. Therefore, an academic/industrial liaison was considered worthwhile and necessary. Initial contact was made with university and government research groups who are currently involved with this research. Of the thirty-three groups contacted, eleven indicated a willingness to participate in such a liaison. From that group, a working relationship has been established with the following:

	Association	Interest
M. Moran	West Chester State University	Inorganic Polymers $(SN)_x$ Polyphosphazene
B. Drago/K. Wagener	University of Florida	Polypyrole, Polyacetylene
F. Karasz/D. Gagnon	University of Massachusetts	PPV

Also listed are the areas of specialization each bring to the research. These researchers have been contracted to provide a selected group of those materials which are considered to have the best possibility as a PTF substitute. At present, we are in the process of synthesizing a number of these materials. These include several intercalated graphites, polypyrole, polythiazyl and poly (p-phenelyne) vinylene. The plan is to perform preliminary evaluation on simple conductor patterns. These will then be analyzed according to the aforementioned criteria for a viable PTF substitute. The research is not necessarily being limited to conventional PTF methods. For example, the concept of positive/negative resist procedures, typically used in thin film electronics, may be applied to PTF/Conductive Polymer. In this approach, a non-conductive precursor could be screened onto a suitable substrate, then polymerized and doped in situ. Such an idea is now being considered with polyphenelyne vinylene.

Future Work

The preliminary Feasibility Study will be extended into the experimental areas mentioned above. The goal of the future work will be to take the conductive materials which meet as many of the PTF criteria as possible, and fabricate test circuits from them. By the end of this study, we hope to have a fundamental understanding of the potential of a polymer thick film/conductive polymer system and will have fabricated simple test circuit patterns for stability testing. Current research and preliminary results are very encouraging.

It is expected that crude, stable prototypes of possibly more than one system may have been prepared by the end of this study (December 15th). At this point we feel confident of presenting a strong Phase II proposal.

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